

STUDIES OF THE GENUS *CULEX* LINNAEUS IN FLORIDA
I. REDESCRIPTION OF THE PUPAE OF *CULEX NIGRIPALPUS* THEOBALD
AND *CX. TARSALIS* COQUILLET, VECTORS OF ST. LOUIS
ENCEPHALITIS, AND A KEY TO PUPAE OF *CULEX* SPECIES IN THE
EASTERN UNITED STATES (DIPTERA: CULICIDAE)

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Abstract.—The pupal stages of *Culex nigripalpus* and *Cx. tarsalis* are redescribed and illustrated. A key to the pupae of 15 species of *Culex* in the eastern United States is included.

Key Words: pupa, *Culex nigripalpus*, *Culex tarsalis*

Culex (Culex) nigripalpus Theobald and *Culex (Culex) tarsalis* Coquillett are both well known vectors of St. Louis encephalitis virus (Monath 1980, Day and Curtis 1999; Day and Stark 1999). *Cx. tarsalis* is also an important vector of western equine encephalitis virus (Reeves and Hammon 1962). It is necessary that all stages of these important species be adequately described, illustrated and recognizable. To that end, the pupae are treated here.

The pupa of *Cx. nigripalpus* was briefly described and figured by Lane (1953). It was illustrated by Belkin et al. (1970) but "not studied in detail." Lungstrom (1955) figured the abdomen and metanotum of *Cx. tarsalis* using the nomenclature of Knight and Chamberlain (1948). He gave no other description. White (1954) discussed the chaetotaxy of the *Cx. tarsalis* pupa in general also employing the nomenclature of Knight and Chamberlain (1948) for the abdomen and that of Penn (1949) for the cephalothorax. In this work, the pupae of both species are described in detail following the generally accepted nomenclature of Belkin (1962) and Harbach and Knight

(1980). Other life stages were described by Carpenter and LaCasse (1955), Belkin et al. (1970, *nigripalpus*), Wood et al. (1979, *tarsalis*).

These pupae may be identified using the key to the pupae of the *Culex* species of eastern United States that appears below and includes 15 of the known 29 species of *Culex* in the United States.

METHODS AND MATERIALS

Specimens of *Cx. nigripalpus* were collected in Indian River and Manatee Counties, Florida, reared individually, and larvae and pupal exuviae mounted in Canada balsam. For details of the techniques, consult Darsie (1998). Pupae of *Cx. tarsalis* examined are listed following the description. In the key that follows the undescribed pupa of *Culex (Melanoconion) peccator* Dyar and Knab was included. Pupae of this species were collected as follows: Florida, Indian River Co., I-16-70, 11 Pe, J. S. Haeger, and will be described later. Abbreviations used in the descriptions are br = branches, LePe = larval and pupal exuviae.

DESCRIPTIONS

Culex nigripalpus Theobald

(Fig. 1)

Description.—Positions and sizes of setae as figured; ranges and modal branchings in Table 1. *Cephalothorax*: Mostly tan, scuta, coxae and femora brown to dark brown. Setae 1,3-CT long, usually triple; 2,4-CT moderately long, usually double or triple 7,9-CT long, usually double or triple; 5,8-CT long, usually 4- or 5-branched. 6-CT short, usually double; 10,12 CT long, 10-CT with 8–12 br, 11,12 CT with 2–5 br; *Trumpet*: Length 0.75–0.82 mm, \bar{x} 0.79 mm, index 5.35–6.75, \bar{x} 6.24, tracheoid 0.20–0.31 of length \bar{x} 0.26; pinna 0.16–0.19, \bar{x} 0.17 mm, without narrow slit extending from proximal aspect, 0.14–0.24 length of trumpet \bar{x} 0.19. *Abdomen*: Length 3.66–4.14 mm, \bar{x} 3.88 mm; tan, segments I–IV darker, with reticulate pattern in dorso-medial 0.25 of I; sternum II with short, sharp spicules along posterior border. Setae 0-II-VII, 9-I-VI, and 14-III-VIII minute, single. Seta 1-I dendritic, with 6–14 primary br, each usually with 9 or more terminal br; 1-II short with 21–37 fine br; 1-III-VII long, III usually with 9 br; mostly quadruple on IV,V; and usually double on VI,VII. Seta 2-II-VII short, single. Seta 3-I-III rather stout, long on I, moderately long on II,III, double; 3-IV-VII moderately long, 4–8 br on IV, usually single or double on V-VII. Seta 4-I-VI short, moderately long on VII,VIII, usually 7-branched on I, usually 4- or 5-branched on II,III and V,VI; single to 4-branched on IV, VII, VIII. Seta 5-I short, usually triple, 5-II,III moderately long, usually with 4–6 br; 5-IV-VI long to very long, stout, 5-IV usually quadruple, 5-V,VI usually double. Seta 6-I very long, single; 6-II-VI long, with 1–3 br on II, mostly double or triple on III-VI; 6-VII small, with 4–6 br. Seta 7-I,II long, mostly double; 7-III-V short, usually 4- or 5-branched on III,V, double or triple on IV; 7-VI,VII long, single. Seta 8-III-VII short, pedunculate, usually 3- or 4-branched on

III, IV and VI; double or triple on V, VII. Seta 9-VII moderately long, stout, with 3–5 primary br, each ending in 2–3 terminal short br; 9-VIII long, stout, usually acuminate, with 6–10 primary br, some ending in 2,3 terminal short br. Seta 10-III-VII long, usually double on III-IV; single (rarely double) on V-VI, 10-VII single. Seta 11-III-VII short, single on III-VI, 1–3 br on VIII. Female genitalia lobe 0.19–0.24 of paddle, \bar{x} 0.21; male genitalia 0.28–0.33 of paddle, \bar{x} 0.30. *Paddle*: Ovoid, light tan, midrib reaching apex, length 0.43–1.03 mm, \bar{x} 0.98 mm; index 1.17–1.51, \bar{x} 1.34; setae 1,2-P short, single.

Specimens examined.—FLORIDA, Indian River Co., Vero Beach, III-29-00, 5 ♀, 6 ♂, LePe, from progeny rearings of females collected by power sweeper in vegetation in wooded area near orange groves (Hussain & Darsie); Manatee Co., Palmetto, VIII-7-2000, 6 ♀, 2 ♂, LePe, from progeny rearings of females collected in miniature light trap with CO₂ (R. Frommer).

Culex tarsalis Coquillett

(Fig. 2)

Description.—Positions and sizes of setae as figured; ranges and modal branchings in Table 2. *Cephalothorax*: Light tan, posterior parts of scutum and mesothoracic wing darker brown. Setae 1,3-CT long, usually triple or quadruple; 2,4-CT moderately long, double or triple, rarely 4-branched; 5-CT prominent, long, triple or quadruple, rarely 5-branched; 6-CT moderately long, with 2–5 br; 7–9-CT long, 7-CT double; 8-CT 3–6 br; 9-CT double or triple; 10-CT long, acuminate, with 5–9 br; 11-CT long, rather stout, double; 12-CT long, mostly double or triple; an adventitious 4-branched seta near 12-CT on one specimen. *Trumpet*: Conical, dark brown, length 0.62–0.92 mm, \bar{x} 0.82 mm; index 4.7–6.2, \bar{x} 5.4; pinna 0.11–0.32 mm, \bar{x} 0.22 mm and 0.18–0.35 of total length, \bar{x} 0.24 without narrow slit extending from proximal end, tracheoid 0.17–0.23, of total length, \bar{x} 0.19. *Abdomen*: Length 3.47–4.02 mm, \bar{x} 3.79 mm; light

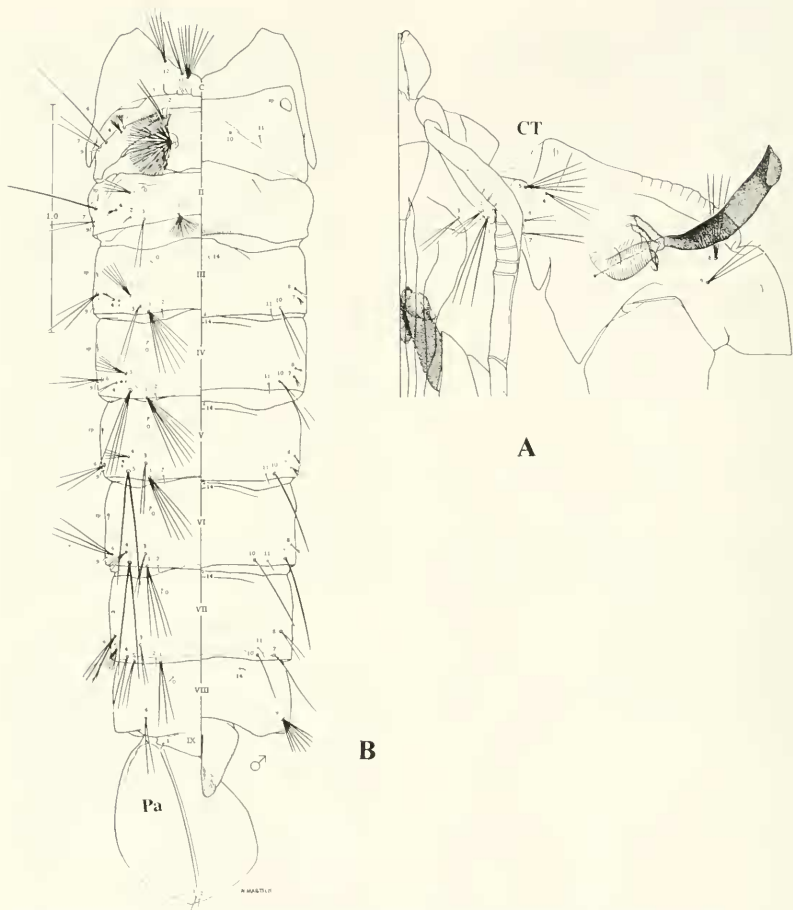


Fig. 1. Pupa of *Cidex nigripalpus*. A. Cephalothorax. B. Metanotum and abdomen (from Belkin et al. 1970, by permission). CT—cephalothorax, Pa—paddle.

tan, 1-IV somewhat darker, without spicules on sternum II. Setae 0-II-VII, 9-I-VI and 14-III-VIII minute, single. Seta 1-I dendritic, with 8-13 primary branches, each branch with 5-8 terminal branches; 1-II moderately long, with 5-13 br; 1-III-VII long, with 5-12 br on III, with 4-8 br IV,

with 3-7, (usually 4) br on V, VI, usually double or triple, seldom with 4 br on VII. Seta 2-II-VII short, single. Seta 3-I long, rather stout, double; 3-II-VII moderately long, double on II, III; with 2-8 br on IV; usually double or triple, rarely single or quadruple on V-VII. Seta 4-I-III short, 4-I

Table 1. Setal branching of the pupa of *Culex nigripalpus* (range is followed in parentheses by the modal branching).

Seta	Cephalo- thorax	Abdominal Segments									
		I	I	III	IV	V	VI	VII	VIII	IX	Paddle
0	—	—	1	1	1	1	1	1	1	—	—
1	1-4(3)	6-14(9)	21-37(27)	5-10(9)	4-7(6)	3-5(4)	2-4(2)	2-3(2)	—	1	1
2	2-4(2)	1-4(1)	1	1	1	1	1	1	—	—	1
3	2-5(3)	2	2	2	4-8(5)	2	1-2(1)	1-2(2)	1-3(2)	—	—
4	2-6(3)	7-9(7)	2-6(4)	4-8(6)	1-4(1)	3-7(5)	2-4(4)	1-2(2)	—	—	—
5	3-6(5)	2-5(3)	3-7(5)	1-7(4)	2-5(4)	2-3(2)	2-3(2)	1-2(2)	—	—	—
6	1-3(2)	1-2(1)	1-3(1)	2-4(3)	2-4(3)	2-3(3)	2-4(3)	4-6(6)	—	—	—
7	2-4(2)	2-4(2)	1-3(2)	3-5(4)	2-4(2)	4-7(5)	1	1	—	—	—
8	3-5(4)	—	—	4-6(4)	4-6(4)	2-4(2)	1-5(3)	2-4(2)	—	—	—
9	2-4(3)	1	1	1	1	1	1	3-5(4)	6-10(?)	—	—
10	7-10(8)	—	—	1-3(2)	2-3(2)	1-2(1)	1	1	—	—	—
11	2	—	—	1	1	1	1	1-3(1)	—	—	—
12	4-6(5)	—	—	—	—	—	—	—	—	—	—
14	—	—	—	1	1	1	1	1	1	—	—

with 5-9 br, 4-II,III usually with 5 br; 4-IV usually double or with 3-5 br; 4-V-VIII medium long, usually with 4,5 br on V,VI; 4-VII,VIII single to triple, rarely quadruple. Seta 5-I short, usually with 3-5 br (2-7); 5-II-III moderately long, usually with 4,5 br, seldom with 6 or 7, 5-IV-VI long, stout, double or triple; 5-VII long, usually double. Seta 6-I,II very long, single; 6-III-VI long, usually triple, 6-VII short, mostly with 6-8 br, rarely quadruple. Seta 7-I,II long, single or double; 7-III short, usually with 6 br; 7-IV,V short, usually with 4 or 5 br, 7-VI,VII moderately long or long, single. Seta 8-III-VII short, pedunculate, usually with 3-6 br. Seta 9-VII long, stout, usually aciculate, with 4-6 br, 9-VIII long, stout, aciculate, with 7-9 br, rarely with 2 br apically. Seta 10-III,IV moderately long or long, usually double, 10-V-VII long, single. Seta 11-VII short, with 1-4 br. *Paddle*: Ovoid, length 0.95-1.35 mm, \bar{x} 1.19 mm; index 1.35-1.56, \bar{x} 1.42; seta 1-P short, single, seldom double or triple; 2-P short, single.

Specimens examined.—MONTANA: Phillips Co., Malta, VII-9-72, 2 ♀, 1 ♂, LePe, (Quickenden, Darsie); Ravalli Co., Hamilton, VIII-5-4, 1 ♀, 1 ♂, LePe, U.S. Public Health Service Rocky Mountain

Laboratory colony (J. M. Brennan). CALIFORNIA, San Diego Co., V-7-49, 2 ♀, 1 ♂, LePe; Otay R., V-8-49, 1 ♀, LePe; Lake Henshaw, V-7-49, 2 ♀; Lake Cuyamaca, V-7-49, 1 ♀ Pe (Heid); Los Angeles Co., Agoura, III-22-49, 1 ♂, Pe (Heid).

DISCUSSION

The pupa of *Cx. nigripalpus* was briefly described by Lane (1953), employing the setal nomenclature of Baisas (1935) as modified by Penn (1949). He stated that the cephalothorax has small tufts, while our account gives accurate branching of each seta. He described the "tube," i.e., trumpet, as three times basal width; in Florida *Cx. nigripalpus* pupal trumpets are 7.8-11.1 \bar{x} 8.9 times longer than basal width. Perhaps Lane was not measuring the same species. In all, 13 abdominal setae were characterized by Lane. His setae 6-II-VI were triple; in our study seta 6-II was usually single, and setae 6-III-VI double to quadruple. Lane called five other setae (1-II, 5-IV,V, 9-VII,VIII) "multiple" without precise branching which we include. Seta 5-VI,VII are listed as double; in our study they are single to triple, although modally double. The paddles in our pupae are 1.9-2.3, \bar{x} 2.1 times

Table 2. Setal branching of the pupa of *Culex tarsalis* (range is followed in parentheses by the modal branching).

Seta	Cephalo- thorax	Abdominal Segments									Paddle
		I	I	III	IV	V	VI	VII	VIII	IX	
0	—	—	1	1	1	1	1	1	1	—	—
1	2-5(3)	8-13(12)	5-13(7)	5-12(7)	4-8(5)	3-7(4)	3-6(4)	2-4(2)	—	1-3(1)	1
2	2-3(3)	1-2(1)	1-2(1)	1	1	1	1	1	—	—	1
3	3-6(4)	2	2	2	2-8(5)	1-3(2)	2-4(2)	1-3(2)	—	—	—
4	2-4(2)	5-9(5)	2-7(5)	4-6(5)	2-5(2)	3-6(5)	2-5(4)	1-3(2)	2-4(2)	—	—
5	3-5(4)	2-7(5)	4-7(5)	4-8(5)	3-5(4)	2-3(2)	2-3(2)	2-3(2)	—	—	—
6	2-5(4)	1	1	2-3(3)	3	3-4(3)	2-4(3)	4-8(8)	—	—	—
7	2	1-2(2)	1-2(2)	3-7(6)	2-4(4)	3-7(1)	1	1	—	—	—
8	3-6(5)	—	—	2-6(5)	2-4(3)	2-4(2)	1-4(3)	3-5(3)	—	—	—
9	1-3(3)	1-2(1)	1	1	1	1	1	4-6(4)	5-10(8)	—	—
10	5-9(6)	—	—	1-3(2)	1-2(2)	1	1	1	—	—	—
11	2	—	—	1	1	1-2(1)	1	1-4(1)	—	—	—
12	2-5(3)	—	—	—	—	—	—	—	—	—	—
14	—	—	—	1	1	1	1	1	1	—	—

length of segment VIII, but Lane reported the paddle three times length of VIII.

On the other hand, Belkin et al. (1970) includes a complete illustration of the pupa and mentioned only the trumpet not flared, its pinna small, the spicules on the posterior margin of sternum II and seta 5-IV usually with 4 branches. Though few, all agree with our findings

Lungstrom (1955) and White (1964) illustrated the abdomen of *Cx. tarsalis* using the Knight and Chamberlain (1948) nomenclature. They are of questionable quality and neither author offered textual description.

KEY TO THE PUPAE OF *CULEX* IN THE EASTERN UNITED STATES

The key was formulated mostly using descriptions by Darsie (1951), Foote (1954), Belkin et al. (1970) and Zavortink and O'Meara (1999), and specimens from the Florida Medical Entomology Laboratory collection. For assistance in using this key, see Figs. 1-2.

- 1. Seta 5-CT very long, ≥ 5.0 length of seta 4-CT; abdominal tergum VIII with posterior lobe overlying lateral part of tergum IX; seta 1-IX absent (subgenus *Micraedes*) *biscaynensis* Zavortink and O'Meara
- 2(1). Meatus of trumpet with narrow slit extending from proximal part of pinna; seta 2-VI usually laterad of seta 1-VI (subgenus *Melanoconion*) 3
- 3(2). Seta 9-VIII very near posterolateral corner *cedeci* Stone and Hair
- 4(3). Seta 5-V double or triple and nearly as long as following tergum 5
- 5(4). Seta 1-II with 14 or fewer branches; pinna of trumpet, including slit, less than 0.3 of total length *pilosus* (Dyar and Knab)
- 6(4). Seta 6-IV,V at least 4-branched; seta 5-V usually 5-branched; trumpet index usually > 8.5 *atratus* Theobald
- 7(6). Pinna including slit ≤ 0.35 length of trumpet; seta 8-CT single *mulremani* Basham
- 8. Pinna including slit ≥ 0.4 length of trumpet; seta 8-CT with 3 or more branches 8

- 8(7). Trumpet lighter in color between apex of tracheoid and base of pinna, flared apically *iolambdis* Dyar
 - Trumpet uniformly dark distal to apex of tracheoid, or if lighter, then remainder of trumpet also lighter, not flared apically *peccator* Dyar & Knab
- 9(2).6 Trumpet index ≥ 7.7 ; seta 9-VII usually double; seta 9-VIII usually 4-branched (Subgenus *Neoculex*) *terriltans* Walker
 - Trumpet index ≤ 7.0 ; seta 9-VII usually with 4 or more branches; seta 9-VIII usually 6-branched or more (subgenus *Culex*) 10
- 10(9). Abdominal tergum I with distinct short spicules posteriorly
 - Abdominal tergum I without short spicules posteriorly 11
- 11(10). Seta 2-P absent on paddle; seta 1,6-VI usually double *restuans* Theobald
 - Seta 2-P present, rarely absent; seta 1,6-VI usually with 3 branches or more 12
- 12(11). Trumpet index rarely \bar{x} 5.0; seta 1-VII usually with 4 or more branches
 - Trumpet index ≥ 5.5 ; seta 1-VII usually double or triple 13
- 13(12). Seta 1-II with 20 or more branches; posterior border of sternum II with sharp, short spicules *nigripalpus* Theobald
 - Seta 1-II with 17 or fewer branches; posterior aspect of sternum II without spicules 14
- 14(13). Trumpet index about 7.0, pinna short, ≤ 0.13 of total length *salinarius* Coquillett
 - Trumpet index ≤ 6.0 , pinna longer, ≥ 0.16 of total length *tarsalis* Coquillett

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